MARINER B ENTRY CAPSULES - SCIENTIFIC SUBSYSTEM

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Scientific objectives

1. Increasing the knowledge of the planet in general
2. Biological information on Mars is the prime objective
3. For Venus the prime objective is a profile of the thermo dynamic variables
4 Photographic observation should be included as soon as it is feasible

Criteria for selection of capsule science

1. Reliability of operation
2. No ambiguity of interpretation of data
3. Sterilizability of all components, especially for Mars
4. Compatability with system constraints
5. Reasonable evolution of knowledge
6. Importance in the development of spacecraft technology
7. Experiments that must use a capsule

Multivator

The multivator is an instrument which measures several biologically important parameters of the planetary environment. The original concept is due to Dr. Joshua Lederberg of the Stanford Exobiology Laboratory and the present design of the instrument is proceeding under the supervision of Mr. Jerry Stuart of JPL.

The multivator consists of eighteen identical cells in which specific chemical, biochemical, and physical measurements can be performed. Each cell consists of two chambers, one of which can be innoculated by a sample of planetary soil while the other contains identical reagents or probes which react without the presence of soil and thus provide a control measurement. The reagents are stored in hermetically sealed time release capsules and released upon initiation of operation. The eighteen cells are mounted on a circular structure and are rotated in sequence into position for sampling. All experiments are designed so that sampling is done optically using either specific spectral responses or scintillation counting of tagged radio chemical isotopes. The present design accomplishes the soil sample collection and injection by placing a soil sample in a hopper situated in the center of the structure, and centrifuging it through a hollow arm at the end of which is a mechanism for picking up a single cell. By this method the cells are innoculated in sequence. The centrifuge also supplies the opportunity to accelerate sedimentation or mixing processes when it is desired. Methods of soil sampling which carry the soil from the planetary surface to the multivator hopper are being investigated in conjunction with various possibilities presented by the capsule configuration.

Table ( ) indicates preliminary ideas outlined by Dr. Lederberg of the parameters to be investigated in the individual cells.

Table 1

Cell	Class of reaction	Specific test	Means of Detection
1	Physical	pH, conductivity, turbidity mass	electrode
2	Enzyme	DNA ase	dialysis membrane - C^{14} in CO_2 detected by scintillation
3	Enzyme	RNA ase	"
4	Enzyme	Protein ase	"
5	Enzyme	D-polypeptide (optical amine)	"
6	Metabolic	glucose	"
7	Metabolic	lactic acid	"
8	Metabolic	complex-peptone	"
9	Metabolic	synthetic L-glucose	"
10	Fluorescent	α -napthyl phosphate (acid substrate)	
11	"	α -napthyl phasphate (alkaline substrate)	
12	"	Nucleotidease-napthyl thymillylate	spectrally sensitive to = 336 m
13	"	RNA & DNA breakdown (ester)	= 460 m
14	"	Leucine amino peptidase	
15	"	α -napthyl-sulfate	
16	"	α -napthyl butyrate	
17	"	choline esterase	
18	"	α -napthyl glucosidase	

The basic multivator without sampling device or internal orientation mechanization) weighs five (5) to six (6) pounds, consumes six (6) watts of power average, uses an information rate of about one (1) bit/sec, requires orientation to within 15^{o} to the gravitational vertical, and needs a minimum of two (2) hours operating lifetime on the planetary surface. If orientation and external sampling must be integral to the instrument the weight and power increase by about a factor of two.

There are obviously many problem areas involved in this instrument and some of these should be mentioned. 1) The reagents used cannot meet the spacecraft specifications for sterilization of 135°C for 26 hours. This is most serious but somewhat amusing since the object of the sterilization program is to maintain the virgin biological environment so that experiments like the multivator will give meaningful results. This state of affairs may persist for all possible biological experiments. We insist upon sterilization so that we can perform our biological experiments upon an uncontaminated environment, but then the spacecraft system designers, after accepting this sterilization constraint, prohibit biological experiments from flying because they are unsterile. The only solution is the multivator sterility must be guaranteed. 2) The reagents must not decompose over the capsule lifetime of 6 to 8 months. 3) So far no acceptable method of sample acquisition has been devised. 4) The presence of the centrifuge motor may prevent the instrument from meeting the spacecraft magnetic specifications.

Modified multivator

Radiochemical Growth probe

This is an instrument which innoculates a radioactively tagged growth medium with planetary soil and measures $C^{14}O_2$ metabolized by any organisms that may be present in the soil. It was conceived by Dr. Gilbert Levin of Resources Research, Inc., and developed by him under a NASA contract.

After the operation sequence is initiated a projectile carries a long string over the planet surface. This string is reeled back carrying soil particles into the growth chamber which contains a universal media whose organic components are tagged with carbon-14. After soil innoculation the chamber is sealed and the fertile sample metabolizes the radioactive material giving off $C^{14}O_2$, carbon-14 dioxide. The $C^{14}O_2$ passes into a detection chamber and the radioactive counts are sampled for short times at hourly intervals and a growth curve is plotted. A positive result combined with a suitable control would indicate the presence of semi-terrestrial type life.

The instrument weighs less than one (1) pound, consumes less than one watt of power, requires a negligible data rate, does not require precise orientation, and needs at least two (2) hours of operating lifetime on the planetary surface.

There are several basic problem areas associated with this instrument. 1) As for the multivator, sterilization may present a difficult hurdle. 2) Controls are needed to show that the growth observed is due to external microorganisms. 3) The media that is used provides a limitation on what types of organisms are detected.

Microscope

An abbreviated microscope used to view microorganisms and particulate matter present in the planetary atmosphere has been proposed by Prof. J. Lederberg of Stanford University and Dr. G. Soffen of JPL.

The microscope will collect aerosols and dust during parachute descent of the capsule, separate them by density, and observe the lighter particles via a simple lens and vidicon system. The optics will have a fixed focus and illuminating system and will examine an object field of 100 microns with a resolution of 0.5 microns. Phase contrast will be used if possible. Each picture will consist of 80,000 bits of information using a square, 200 line raster and four shades of gray.

The recognition of microbes under a microscope is not simple but certain features are strongly indicative. Most terrestrial forms have a regular geometrical shape and occur within a certain size. Many organisms and cells contain internal organelles or intricate architecture. If such were observed, it could in some cases establish, beyond any reasonable doubt, the presence of life.

It is estimated that this instrument be designed to weigh less than three (3) pounds, occupy a volume of less than 500 cubic inches, require less than one watt for illumination, can be made rugged and sterilizable, and can remain in standby conditions for at least 300 days.

There are two major problem areas, 1) requirement of either a high data rate or on board storage, 2) reliable sample acquisition and handling.

Gas Chromatograph (biology)

The gas chromatograph is more fully discussed under the atmospheric composition instruments and is included here to emphasize its application to the detection of organic compounds that would be indicative of the state of evolution of planetary life. It presents the advantage of studying the biochemical environment and obviates the necessity of assuming terrestrial type life in the design of biological experiments. The "biological" gas chromatograph differs from the atmospheric g-c mainly through the sampling mechanism and the choice of columns.

Temperature

The temperature will vary from 100°K to 300°K on Mars and from 200°K to more than 600°K on Venus, depending upon the height in the atmosphere, the latitude of capsule entry, and local planetary "daytime." Since latitude and local time cannot be known within wide limits for the Mariner B capsules, a few spot measurements of temperature at various altitudes are clearly meaningless. However, these variations in local conditions probably will not affect the general temperature profile of the atmosphere which should be relatively constant over the planetary sphere. Thus temperature measurements must be correlated with simultaneous height determinations. The radar altimeter discussed in another section provides a straightforward approach to height measurements. If this is unavailable, height information must be deduced indirectly by integration of the hydrostatic equation. Appendix C indicates the method and a sample calculation. Temperature measurements during descent must be made such that the distance between samplings does not exceed 500 feet.

The thermometer will be either a thermistor type of a fine tungsten resistance wire. Preliminary studies indicate that the latter would have a shorter response time and be less sensitive to non-atmospheric heat sources. For Mars the dynamic range should be from 100°K to 300°K with an accuracy of about ± 1°K. For Venus the range should be 200°K to 1000°K with an accuracy of ± 5°K. The difference in accuracies reflects the fact that the knowledge of Mars is considerably more precise than that of Venus.

Weight and power are minimal, (a few grams and less than 1 watt), the data rate depends upon descent velocity but should be about 1 bits/second. The thermometer should operate continuously during descent and after impact to pick up height variations and diurnal changes.

The main problem area is selection of appropriate mounting on the capsule structure so that the temperature that is measured is truly the ambient temperature.

JPL is presently requesting design study contracts for construction of this instrumentation. It is felt, due to the intimate relationship between the thermometer and the capsule design, that this program should proceed with close liaison between the experimenter and the capsule design engineers.

Pressure

The pressure on the Martian surface is between 50 and 100 millibars with a nominal value of 85 mb. Important parameters to measure are the pressure profile, the surface pressure, surface diurnal and seasonal pressure variations, and short term pressure fluctuation. The surface pressure is critical in calibrating spectrometric measurements taken by the bus. The pressure profile is interesting in itself and in conjunction with the temperature measurements permits a relative height determination through integration of the hydrostatic equation. The pressure variations mentioned above are probably second generation experiments.

On Venus the surface pressure is unknown. Estimates that it is several tens of atmospheres are common. As with temperature, the surface pressure on Venus will be extremely critical in the design of future soft landing spacecraft so that knowledge is necessary as soon as possible.

Pressure measurements should be taken simultaneously with the temperature measurements. The type of transducer has not been selected and may be quite different for Mars and Venus. Weight, power and communication requirements are similar to the thermometer as is the necessity for correct placement on the capsule structure. The dynamic range on Mars should be from 0 to 150 mb with an accuracy of $\pm$ 1 mb. On Venus the range would be from 0 to 200 atmosphere (probably two transducers) with an accuracy of 2% from 0 to 1 atm. and $\pm$ 1 atm. in the rest of the range.

Contrary to the situation with the temperature, a few isolated pressure samplings would be valuable, especially if they were made at the surface, since the pressure variation over the sphere would be comparable to the fluctuations of pressure at a single point. As with the temperature, if the surface relief is large, ambiguity will result in the interpretation of surface pressure data.

JPL is presently requesting design study contracts for construction of this instrumentation.

Density

In conjunction with pressure and temperature, and, assuming the perfect gas law, the density will give the molecular weight which will provide a rough indication of the composition. So far the only instrument proposed is an electron absorption apparatus which has been developed for terrestrial atmospheric density measurements up to 150,000 feet.

The gauge consists of a source of beta particles separated from a detector by a fixed distance. The beta ray attenuation coefficient is relatively independent of composition for the items of interest. Weight less than 1 pound, power is less than 1/2 watt, information rate is comparable to temperature and pressure instrumentation. The same system integration problems are anticipated as with the other thermodynamic measurements.

JPL is presently requesting design study contracts for construction of density measuring instrumentation.

Velocity of sound

Many proposals have been made using the measurement of the velocity of sound as a probe for compositional and thermodynamic parameters. The basic equation is $v^2 = \frac{\gamma RT}{M}$ where γ is the effective ratio of specific heats, R is the gas constant, T is the absolute temperature and M is the effective molecular weight. Since T and M will be measured by other parts of the thermodynamic package, measurement of v will indicate a value for γ. Thus we will know both γ and M and the possibilities for various compositions will be narrowed considerably. Appendix C indicates quantitatively how good this knowledge will be for the various assumed compositions.

The instrument should operate using resonance of standing waves since this is most reliable, easier to mechanize, less subject to instrumental effects, and less dependent upon external conditions. It is hoped that the system requirements will be similar to other thermodynamic instrumentation.

JPL is presently requesting design study contracts to develop this instrumentation.

Gas chromatograph (atmospheric composition)

The gas chromatograph separates various components by using their different retention times in an adsorption or fine capillary column. By suitable column selection almost any molecular or atomic species can be investigated. The feasibility of incorporating this instrument in a spacecraft has been extensively investigated in connection with the Surveyor program. The planetary instrument will investigate the following gases with emphasis on those marked by an asterisk; N_2*, CO_2*, A*, H_2O*, O_2*, CO*, CH_4*, H_2*, O_3*, NH_3*, H_2S, nitrogen oxides, C_2H_6, Kr, Xe, He, Ne. The limit of detection is 10 ppm at the surface level.

The instrument is designed to operate both during descent and after impact. Weight is less than 5 lbs., power is four (4) watts. Each sampling requires a total of 400 bits of information.

Two possible problem areas are 1) sufficient equilibration time prior to operation, 2) sampling.

The gas chromatograph is capable, with suitable modification of the sampling system, of making complete organic and inorganic analysis of the planetary soils.

The program is supervised by the joint efforts of Mr. Vance Oyama of JPL, Prof. James E. Lovelock of Baylor University and Prof. S. R. Lipsky of Yale University.

Mass spectrometer

The mass spectrometer can detect compounds, atoms, and isotopes present in the planetary atmosphere. This device is being developed extensively for use in terrestrial sounding rockets. Several types of instruments are being considered, magnetic sector, quadrupole electrostatic mass filter, r-f spectrometer, and various other applications of the time of flight principle.

JPL has released a request for design study for a spectrometer that meets the following constraints:

Weight - five (5) pounds or less

Power - six (6) watts or less

Sensitivity - 0.1 volume percent components

Accuracy - ± 10% on 10% components

± 5% or better on 80% components

Resolution - $M/\delta M = 25$ or better

Mass ragge - 12-50 amu

Scanning time - 20-60 seconds

Sampling - one or more samples repeesentative of the planetary atmosphere.

"Simple" composition

Simple composition refers to the concept of building separate small instruments to measure specific components of the planetary atmosphere. These are designed as a backup to the complete spectrum instruments like the gas chromatograph or the mass spectrometer and will be included on the capsule if system constraints prohibit the inclusion of these more complicated instruments. JPL has received and reviewed proposals to build instruments to detect H_2O, O_2, O_3, CO^2 and N_2. They all meet the desired constraints of 1 pound, 1/2 watt, and minimum data rate specified by the JPL request.

Experimental philosophy

At present it is impossible on technical grounds to choose which of the three approaches to compositional analysis should be selected for flight items. Assuredly they each will be included in some future mission so that preliminary study of each is warranted. After the completion of the design studies a choice will be made as to which of the three will be selected for breadboard construction and flight. Only one can be flown.

Television

No studies are underway to include a television system on a Mariner B capsule in 1964. Almost certainly, however, later editions of the capsule which have a greater communication capability will carry a TV system. Television technology is well advanced, however, so that it could easily be incorporated at any time the system would permit. The instrument parameters would be adapted to fit the total mission constraints.

Facsimile camera

The attached JPL interoffice memo (Appendix F) discusses an exciting device which could with only slight modification be incorporated in the 1964 Mariner B capsules. This device would transmit a complete, 360° picture of the capsule horizon plus resolution of the local capsule area to a few millimeters. It would also be an absolute photometric device that would measure reflectivities, solar radiation, and atmospheric transmission. Some color indexing may also be possible.

Wide band spectrophotometer and UV photometer

This instrument would use the Sun as a source and measure the transmittance of the planetary atmosphere in several selected wide wavelength regions. This measurement would provide, in rough fashion, the following information: 1) Surface ultraviolet radiation intensity whose presence is inimical to living organisms as we know them, 2) ozone content of the atmosphere (UV spectrophotometer), 3) radiation data for computation of meteorological models, 4) visible windows in the Venusian atmosphere whose presence would permit surface surveys from flybys or orbiters, 5) the presence and possible composition of clouds.

Major problem areas are: 1) The elevation of the Sun would be unknown so the instrument must operate the same with radiation from anywhere in the hemisphere of view, 2) Atmospheric scattering, 3) Filter selection and design.

At present, no work is being done on an instrument of this type. Interested scientists should be encouraged to participate in this vital measurement.

Electromagnetic induction of the surface

This instrument would measure the intensity and phase of electromagnetic waves scattered from the planetary surface. Qualitative measurement of soil type and wetness should be feasible. This experiment was proposed by Dr. Elliott Levinthal of the Stanford Exobiology Laboratory. The Conductron Corporation has studied the feasibility of instrumentation and concluded that an instrument weighing 9 lbs and consuming 9 watts can perform the job. They have presented preliminary data indicating how the measured parameters correspond to various soil types and wetness.

It is improbable that the instrument can be carried on the 1964 capsules.